Technical Paper Series Macroeconomic Analysis and Tax Analysis Divisions Congressional Budget Office Washington, D.C.

# Draft Framework for Determining the Spreads of Commercial Paper Rates and LIBOR to the Rate on Three Month Treasury Bills and the Volatility of those Interest Rates

Robert Arnold, Angelo Mascaro, Matthew Salomon with the research assistance of David Arnold Macroeconomic Analysis Division Congressional Budget Office

**July 1999** 

# 1999-7

Technical papers in this series are preliminary and are circulated to stimulate discussion and critical comment. The analysis and conclusions expressed in these papers are those of the authors and do not necessarily represent the position of the Congressional Budget Office. References in publications should be cleared with the authors. Papers in this series can be obtained by sending an email to techpapers@cbo.gov.

# Table of Contents

INTRODUCTION	1
BACKGROUND ON THE ALTERNATIVE RATES	2
Market Size and Major Characteristics	
Treasury Bills	2
Commercial Paper	3
London Interbank Dollar Deposits (LIBOR)	3
Determinants of Yields and Spreads of the Alternative Rates	4
Treasury Bill Rates	6
Commercial Paper Rates	6
LIBOR	7
Why Spreads Have Narrowed	10
Determinants of Volatility of the Alternative Rates	11
PROJECTIONS OF THE SPREADS	13
How CBO Currently Projects Rates	13
A Model for Projecting Commercial Paper Rates and LIBOR	14
One-month Commercial Paper—Three-month Treasury Bill Spread	15
Three-month Commercial Paper—Three-month Treasury Bill Spread	16
One-month LIBOR - Three-month Treasury Bill Spread	17
Three-month LIBOR - Three-month Treasury Bill Spread	19
Spreads of Eurodollar Deposit Rates to Three-month Treasury Bill Rates	20
Forecast of Volatility of Alternative Instruments	22
Uncertainty Associated with Explanatory Variables	23
Uncertainty Associated with the Alternative Rates	24
Probabilities Associated with Alternative Rates	24

# TECHNICAL APPENDIX: ESTIMATION METHODOLOGY AND ECONOMETRIC DETAIL 25

# TABLES

1.	Relative Size of Markets	2
2.	British Bankers' Association List of 16 Banks Used to Construct LIBOR	5
3.	Spread to Three-Month Treasury Bill Rate of Alternative Short-Term Rates	5
4.	Volatility and Level of Commercial Paper Rate and LIBOR to Treasury Bill Rate	11
5.	Average Spreads of LIBOR to Eurodollar Deposit Rates	19
6.	Illustrative Baseline for Commercial Paper Rate, LIBOR, and Eurodollar Rates	21
7.	Average Levels of Determining Factors	22
8.	Illustrative Probabilities for Alternative Interest Rates	25

# APPENDIX TABLES

1	Ordinary Least Squares Estimates of Interest Rate Spreads	28
2.	Autoregressive Conditional Heteroskedastic Model of Squared Residuals	29
3.	Generalized Least Squares Estimates of Interest Rate Spreads	30

# FIGURES

1.	Percentage Distribution of Issuers of Commercial Paper	3
2.	Distribution of Holder Of Commercial Paper	4
3.	Spreads of 3-Month and 1-Month Commercial Paper Rates to 3-Month Treasury Bill	7
4.	Spreads of 1-Month LIBOR and Commercial Paper to 3-Month Treasury Bill	8
5.	Spreads of 3-Month LIBOR and Commercial Paper to 3-Month Treasury Bill	8

FIGURES - con't

6.	Spreads of Fedfunds and 1-Month LIBOR and Commercial Paper to 3-Month TBill	9
7.	One and 3-Month Spreads between LIBOR and Commercial Paper	10
8.	Volatility of Spreads to TBill, 1972Q1 - 1998Q4	12
9.	Inflation and the Volatility of the 1-Month LIBOR to 3-Month Treasury Bill Spread	13
10.	Spread of 1-Month Commercial Paper versus 3-Month Treasury Bill	16
11.	Spread of 3-Month Commercial Paper versus 3-Month Treasury Bill	17
12.	Spread of 1-Month LIBOR versus 3-Month Treasury Bill	18
13.	Spread of 3-Month LIBOR versus 3-Month Treasury Bill	18
14.	Spread of 1-Month Eurodollar versus 3-Month Treasury Bill	19
15.	Spread of 3-Month Eurodollar versus 3-Month Treasury Bill	20

### INTRODUCTION

The Higher Education Amendments of 1998 direct CBO and other organizations to participate in a study group which shall evaluate the spread between each of the 30-day and 90-day commercial paper rates, and the 90-day London Interbank Offered Rate (LIBOR) to the 91-day Treasury bill rate. The study group, chaired by the Comptroller General (GAO) and the Secretary of Education, has asked CBO to present an illustration of its projections of these spreads as well as that between 30day LIBOR and the 91-day Treasury bill rate. The study group has also asked CBO to present illustrations of probability ranges for the levels of commercial paper, London interbank, and Treasury bill rates which would emerge from these projections. The levels and volatilities of these interest rates would be used in CBO's probability scoring of proposed changes to the federal studentloan programs. Under current legislation due to expire in 2003 federal student loan programs use the 91-day Treasury bill rate in the context of various formulas that establish payments by students, receipts by lenders, and special allowance payments by the federal government. Though CBO makes projections of the 91-day Treasury bill rate, it currently makes no projections of the alternative rates considered here. The CBO did prepare one-time projections of rates on commercial paper and LIBOR in 1997, however, when these rates were first proposed as alternatives to Treasury interest rates for use in the Federal Student Loan program.

This paper provides illustrative projections for the spreads of one- and three-month commercial paper rates and one- and three-month London interbank offer rates (LIBOR) to the interest rate on three-month Treasury bills. Projections are also included for spreads of one- and three-month Eurodollar rates to the rate on three-month Treasury bills. The projections are illustrative because CBO does not currently make forecasts for commercial paper and LIBOR. The projections are consistent with the economic assumptions discussed in the Congressional Budget Office's January 1999 outlook, *The Economic and Budget Outlook: Fiscal Years 2000-2009*.

The paper provides a brief background on the instruments, a discussion of the determinants of the spreads and their volatility, a summary of the quantitative procedures developed for the illustrative projections, and a summary table that consolidates information on the projections for commercial paper and LIBOR, given the outlook for Treasury bill rates from CBO's January 1999 budget outlook. Following that is a description of CBO's methodology for developing probability bands around the baseline outlook, and illustrative results for the interest rates examined in the paper. A technical appendix provides additional discussion of the methodology and presents econometric information on the projection equations.

The paper is being issued in draft form to solicit comment prior to issuing a final version. It is being distributed to staff of the Committee on Education and the Workforce of the U.S. House of Representatives and the Committee on Health and Education of the U.S. Senate, members of the federal student loan working group, CBO's panel of economic advisers, and other interested individuals and organizations.

## **BACKGROUND ON THE ALTERNATIVE RATES**

# Market Size and Major Characteristics

Treasury bills, commercial paper, and London interbank deposits of U.S. dollars are all instruments of the money market--that segment of the capital market encompassing short-term financial instruments. The money market gives issuers a flexible debt-management tool for smoothing cash flows and managing various balance-sheet exposures. It gives holders a financial asset with cash-like properties to better manage investment portfolios.

Of the markets for the three instruments, the largest is that for commercial paper (see Table 1). It became the largest of the three markets in the late 1980s, spurred on by the surge in financial intermediation and innovation. Once the largest of the three as measured by the dollar volume outstanding, the Treasury bill market has fallen to second place and could fall behind the London interbank dollar market within the next decade if federal surpluses persist. The London interbank dollar market is about one-half the size of the commercial-paper market and is growing more slowly. Since 1980, the London interbank market has grown at about 5.2 percent per year compared with growth in the commercial paper market of 10.9 percent per year. It is uncertain how future growth of the London interbank dollar market will be influenced by the launching of the Euro and other aspects of the monetary unification in Europe.

		Commercial Paper	London Interbank
	Treasury Bills	Outstanding	Dollar Deposits
1970:	76	33	48
1980:	200	164	195
1990:	482	610	397
1997:	715	958	487
1998:	691	1,161	494

#### Table 1. Relative Size of Markets (\$billions)

Sources: Treasury Bills: Economic Report of the President; Commercial Paper: Flow of Funds Accounts; London Interbank Dollar Deposits: Bank for International Settlements Forty-Fifth Annual Report for 1970, and Bank of England, Monetary & Banking Statistics for other years.

#### Treasury Bills

Treasury bills are issued by the Federal government as a means of financing deficits, in maturities of 13, 26, and 52 weeks, and in denominations of up to \$1 million. Treasury bills are distinguished from other money market instruments by their perception as an instrument free from default or credit risk, and as having a high degree of moneyness or liquidity--their ready acceptability by a wide variety of investors here and abroad and their easy resale ability in turbulent markets as well as

during normal economic and financial conditions. Though a breakdown of overall Treasury-debt ownership is available, no regularly available breakdown of holders of Treasury bills exists.

#### Commercial Paper

Commercial paper is issued in maturities up to 270 days (longer maturities would trigger registration requirements of the Securities and Exchange Commission), in amounts ranging upwards of several million dollars. Issuers mostly include funding corporations of nonfinancial firms, finance companies, issuers of asset-backed securities, funding subsidiaries of banks, and analogous foreign entities (see Figure 1). Holders include money market mutual funds (which tend to dominate), retirement-type entities (trusts, public and private pensions, and insurance), banks, corporations, and various foreign entities including foreign governments and central banks (see Figure 2).



NOTE: "Other" includes Commercial Banking and REITs; ABS = Asset Backed Securitizers.

# London Interbank Dollar Deposits

London interbank deposits of U.S. dollars are funds placed in large amounts at fixed maturities in international banks in London and loaned and borrowed among those banks in what is called the interbank market. The deposits themselves--known as Eurodollar deposits--come originally from other financial institutions, large corporations, individuals, and governments. The lending and borrowing of these deposits among banks, which is the defining characteristic of this market, mostly reflects cash- and risk-management activities by individual banks in relation to their domestic and international operations.



**Figure 2. Percentage Distribution of the Holders of Commercial Paper** 

NOTE: "Other" includes Nonfinancial Corporate Business, Monetary Authority, Commercial Banking, Savings Institutions, Credit Unions, Bank Personal Trusts and Estates, Private Pension Funds, State and Local Government Retirement Funds, Government Sponsored Enterprises, and Brokers and Dealers.

SOURCE FOR FIGURES 1 & 2: CBO calculations based on data from the Federal Reserve Board of Governors.

Rates on London interbank dollar deposits are quoted on an offer and bid basis. The rate asked by the lender is the offering rate--LIBOR for London interbank offered rate, and the rate on funds wanted by the borrower is the bid rate--LIBID for London interbank bid rate.

The British Bankers' Association compiles a measure of LIBOR from a sample list of participants that changes as conditions warrant. The 1999 panel of contributing banks is shown in the following table, along with each bank's home country (see Table 2).

## **Determinants of Yields and Spreads of the Alternative Instruments**

Overall levels of interest rates on Treasury bills, commercial paper, and London interbank deposits of dollars are determined by inflation and expectations of inflation and by overall conditions of demand and supply in credit markets which, in turn, are importantly influenced by the stance of monetary policy. In general, however, rates on Treasury bills tend to average lower (see Table 3).

Table 2. British Bankers' Association List of 16 Banks Used to Construct LIBOR

Bank	Home Country
Bank of America Chase Manhattan Bank Citibank	United States
Abbey National Barclays Bank HSBC Lloyds Bank The Royal Bank of Scotland National Westminster Bank	United Kingdom
Bank of Tokyo Mitsubishi The Fuji Bank The Norinchukin Bank	Japan
Credit Suisse First Boston UBS	Switzerland
Deutsche Bank Westdeutsche Bank	Germany

Source: British Bankers' Association

TABLE 3. Spread to Three-Month Treasury Bill Rate of Alternative Short-Term Rates								
1960-1998 1971-1998 1980-1998 198								
Commercial Paper: 1-month	0.48	0.53	0.55	0.46				
3-month	N.A.	0.39	0.36	0.41				
LIBOR: 1-month	1.13	1.13	1.01	0.68				
3-month N.A. 1.31 1.13 0.77								
N.A. = not available Source: CBO calculations based on data from Federal Reserve, London <i>Financial Times</i> .								

Differences among interest rates on Treasury bills, commercial paper, and London interbank deposits depend on factors influencing the comparative risk and return structures of the instruments. These factors are determined by the characteristics of the participants who issue, market, and hold the instruments and by the institutional and legal arrangements governing participants and markets. Generally, the differences widen when inflation and inflation expectations increase, or when

monetary policy becomes tighter or more volatile. During these occasions, differences in riskiness among the three instruments intensify with the result that spreads themselves widen.

#### Treasury Bill Rates

Interest rates on Treasury bills are mostly influenced by inflation expectations and by overall conditions of demand and supply in credit and goods markets, including perceptions about risk and uncertainty. Interest rates on Treasury bills contain an inflation premium to compensate holders for any expected loss of purchasing power. At the same time, however, Treasury bills probably have little or no liquidity premium--compensation for holding bills instead of cash--because holders have a ready market in which to sell Treasury bills should they need cash before the Treasury bills mature. For large transactions, the bills themselves could be used for payment. Treasury bills also do not contain a credit-risk premium--compensation to offset the chance the issuer might default-- owing to the credit standing of the federal government. In fact, during turbulent times, the desire for safe assets tends to produce unusually low interest rates on Treasury bills compared to money-market instruments issued by private-sector entities.

#### Commercial Paper Rates

Interest rates on commercial paper are typically higher than rates on Treasury bills, mostly because of liquidity and credit-risk premiums. While these premiums are not directly observable, their presence is subsumed in the spread between commercial paper rates and Treasury bill rates (see Figure 3).

The spread between commercial paper and Treasury bill rates widens when overall interest rates rise, when inflation rises, and when monetary policy is tightened. The spread narrows when those conditions are reversed. That is probably because high interest rates, high inflation, and tight monetary policy tend to amplify the liquidity premium and credit-risk premium of commercial paper compared to Treasury bills.

Interest rates on commercial paper are generally higher than rates on Treasury bills partly because commercial paper is less liquid than Treasury bills-- commercial-paper holders might not readily find a buyer should they wish to sell prior to maturity of their commercial-paper holdings. At the same time, however, purchasers normally expect to hold commercial paper to maturity and the influence of this lesser liquidity on the spread of commercial paper over Treasury bills is judged normally to be small. As already noted, the liquidity premium varies with the monetary policy cycle, rising for example when monetary policy tightens and reduces liquidity, and conversely.

Interest rates on commercial paper are also generally higher than rates on Treasury bills because commercial paper rates contain a credit-risk premium--compensation holders demand because issuers of commercial paper can encounter unexpected financial difficulties that might jeopardize their solvency or at least their ability to honor their commercial paper obligations on time. The economy's cyclical position influences the credit-risk premium, causing the spread to shrink during periods of economic expansion when concerns for credit risk might lapse, and causing the spread to rise abruptly during economic downturns when financial difficulties surface.



Figure 3 Three-Month and One Month Commercial Paper Rates: Spreads vs. Rate on 3-Month T-Bill

SOURCE:CBO calculations based on data from the Federal Reserve Board of Governors.NOTE:Shaded areas indicate US recessions.

Finally, the credit and liquidity premiums both tend to widen substantially when financial markets move from normal to turbulent periods. In such times, potential holders become more risk averse and seek safe haven in instruments such as Treasury bills.

### **LIBOR**

Spreads between LIBOR and Treasury bills tend to be higher than those between commercial paper and Treasury bills, though the gaps have narrowed over the past few years (see Figures 4 and 5). Rates on London interbank dollar deposits do contain liquidity and credit-risk premiums like those on commercial paper. As a result, they also should vary with overall interest rates, inflation, and monetary policy. However, because the instruments in both markets are denominated in dollars, the difference in the spreads probably stems from differences in participation and possibly location that produce stronger liquidity and credit-risk premiums in rates on London interbank deposits than in rates on commercial paper.



Figure 4. Spreads of 1-month LIBOR and 1-month Commercial Paper to 3-month TBill.

Figure 5. Spreads of 3-month LIBOR and 3-month Commercial Paper to 3-month T-bill.



Sources for Figures 4 and 5: Federal Reserve, British Bankers Association.

Three factors apparently have accounted for the higher spreads for LIBOR versus commercial paper, though no systematic analysis has quantified the degree of their influence. First, the London interbank market for dollar deposits is linked closely to the interbank market for Fedfunds--the reserves banks have on deposit at the Federal Reserve and buy and sell among each other (see Figure

6). For example, a U.S. bank needing reserves to meet its regulatory requirement to hold reserves in proportion to demand deposits can meet that requirement by borrowing Fedfunds from another bank in the U.S. or by borrowing Eurodollars from a bank in London. London interbank dollars, Fedfunds, and commercial paper all trade on an unsecured basis and this induces credit-risk premiums in their interest rates relative to the rate on Treasury bill. However, banks typically operate with much higher leverage than do nonbank financial institutions such as finance companies. That higher leverage might produce higher credit-risk premiums for banks and thus for interbank rates to the extent that banks are perceived to be riskier than participants in commercial paper. At the same time, however, a participant in the London interbank market does have access to its home country's central bank and that might be a mitigating factor in the bank premium.



Figure 6. Spreads of Fedfunds, 1-month LIBOR and Commercial Paper to 3-month Treasury Bill Rate

Second, country risk may play an important role as well. A bank's home country might itself be a source of risk because of its economic and financial circumstances, its regulatory policies, or its political situation, any or all of which cause the bank to be willing to pay a premium for the funds it borrows through the interbank market. As a result, this premium could influence the measure of LIBOR compiled by averaging rates from banks with different home countries. The size of this premium can be expected to vary through time.

Finally, banks have been subject to reserve requirements and deposit insurance premiums that should also drive a wedge between LIBOR rates and commercial paper rates. However, research attempting to determine the size of that effect has not shown it to be very significant.<sup>1</sup>

<sup>1.</sup> For additional discussion of regulatory effects see, Richard C. Marston, *International Financial Integration: A Study of Interest Differentials Between the Major Industrial Countries*, (Cambridge, England: Cambridge University Press, 1995).

#### Why Spreads Have Narrowed

The LIBOR-TBill spreads have moved close to the commercial paper-Treasury bill spreads since the early 1990s, resulting in a very narrow spread between LIBOR and commercial paper (see Figure 7). Since the early 1990s, the spread between LIBOR and commercial paper has averaged about 23 basis points for the 3-month spread and about 15 basis points for the 1-month spread.





An important reason for the narrowing of the spread between LIBOR and commercial paper probably stems from the favorable circumstances facing money markets. Throughout the 1990s, monetary policy has become progressively more stable--the rate on Fedfunds has become less volatile compared to past decades and the Federal Reserve has tended to provide more information with which market participants can anticipate changes in monetary policy. With low volatility, the overall liquidity and credit-risk premiums might have been reduced, narrowing differences in liquidity and credit-risk premiums between London interbank and commercial paper rates. Another reason might just be the low level of interest rates themselves that also has greatly benefitted money markets and reduced spreads among short-term interest rates.

Spreads between LIBOR and commercial paper have probably also narrowed as a result of the closer integration of domestic and international financial markets. That integration was facilitated by the technological advances in computers and telecommunications that have enabled issuers and holders to shift among the Eurodollar market, the commercial paper market, and other money and capital markets in such a way as to globalize money markets and reduce the spreads relative to the past. Advances in finance have also played a role. For example, the rise in the interest-rate swaps market has increased the connection between the commercial paper and London interbank markets.

Yet another factor in the narrowing of the LIBOR-commercial paper spread could be the lapse of regulatory influences cited earlier. Reserve requirements imposed by the Federal Reserve on funds borrowed abroad have been eliminated since 1990; and insurance premiums on bank deposits have been reduced since the mid-1990s in response to the replenishment of insurance funds administered by the Federal Deposit Insurance Corporation and the stronger capital position of banks. No doubt other reasons can be found as well.

# **Determinants of Volatility of the Alternative Rates**

A striking feature of the decline in spreads of commercial paper rates and LIBOR relative to the rate on Treasury bills has been an associated decline the volatility of those spreads. Most of the decline in volatility has occurred since the middle 1980s (see Table 4 and Figure 8).

Table 4.Volatility and Level of Commercial-Paper Rate and LIBOR Spreads to TBill Rate 1972- 1984 versus 1985-1998							
Commercial Paper to 3-Month TBill LIBOR to 3-Month TBill Rate Rate							
Volatility of Spread*	One-Month	Three Month	One-Month	Three-Month			
1972-1984	0.32	0.24	0.51	0.55			
1985-1998	0.12	0.13	0.15	0.15			
Level of Spread							
1972-1984	0.62	1.55	1.82				
1985-1998 0.46 0.41 0.68 0.77							
* Average of four-quarter, sample standard deviation of quarterly spread.							



Figure 8. Volatility of Spreads to TBill 1972Q1- 1998Q4 (volatility is defined in Table 3)

What explains the decline in the volatility of the spreads? It is unlikely to be due to financial market developments alone. In fact, such financial-market events as the Asian financial turmoil, the Russian debt default, and others have had opposite effects. Instead, a likely source of reduced interest-rate volatility is the substantial decline in inflation which has helped to improve the overall climate in financial markets. Its timing coincided with the decline in volatility, just as the surges in inflation in the 1970s and early 1980s coincided with jumps in interest-rate volatility (see Figure 9).

Inflation affects interest-rate volatility through diverse channels. A sustained period of low inflation helps financial markets to work more efficiently and leads businesses to focus on improving productivity and operating efficiency. Eventually, profitability is improved, balance sheets are strengthened, and perceived risks associated with investing for the long term are reduced, all of which ultimately contribute to reduced volatility in asset returns and interest rates.<sup>2</sup> Thus, when unanticipated shocks erupt, such as those in Asia and elsewhere, such companies that issue commercial paper and such banks that borrow in the London dollar market are not perceived to be in jeopardy. The associated interest rates do not react as adversely as otherwise, and volatility is smaller.

<sup>2.</sup> For additional discussion see Testimony of Chairman Alan Greenspan, "the Federal Reserve's semiannual monetary policy report," Committee on Banking, Housing, and Urban Affairs, U.S. Senate, July 18, 1996.

Figure 9. Inflation and the Volatility of the 1-month LIBOR - 3-month TBill Spread [Inflation = left scale; volatility = right scale.]



#### PROJECTIONS OF THE SPREADS

#### **How CBO Currently Projects Interest Rates**

CBO's budget outlook, prepared annually with an update at midyear, does not contain an outlook for commercial paper rates or LIBOR but does contain an outlook for Treasury interest rates. The budget outlook spans a horizon of 10 years. It consists of a short-term projection for a two-year span adjoined with a medium-term projection for the remaining 8-year span. The 2-year projection embodies an attempt to describe the likely evolution of the business cycle. It is usually quite close to the Blue Chip consensus forecast. For the long-term projections, CBO does not try to project cyclical movements but instead attempts to approximate typical relationships--taking account of the possibility of booms and recessions. CBO uses historical data to identify trends in factors such as the growth of the labor force, the rate of national saving, and the growth of productivity. For Treasury interest rates, the projections are based on underlying trends of real interest rates and inflation, and reflect CBO's baseline projections of government borrowing needs.

CBO prepared special projections of rates on commercial paper and LIBOR in 1997 when these rates were first proposed as alternatives to Treasury rates for use in the Federal Student Loan programs. For rates on commercial paper and LIBOR, the 2-year segment assumed an adjustment from their current cyclical position to a level in the medium-term projection period that, in turn, was determined by the historical average spread to the rate on 3-month TBill. The adjustment to the historical average spread was assumed to have been completed within two years.

which the historical average was calculated was from the early 1970s to late 1997, a period encompassing shocks such as from the commercial paper default of Penn Central Railroad near the start of the 1970s, the shift to floating exchange rates in the early 1970s, the oil shocks of the mid and late 1970s, the default of the German bank Herstatt in mid-1974 that affected LIBOR, the monetary policy shock of the late 1970s and the sovereign debt crisis of the early 1980s. Those shocks affected both commercial paper and especially LIBOR spreads to Treasuries.

The Asian-related turmoil of 1998 provided an important test for interest rates, however, one that suggests the need to augment the approach taken in 1997 for determining spread of commercial paper rates and LIBOR relative to the rate on the 3-month Treasury bill. During the turmoil, spreads rose sharply but not to the extent observed during the 1970s to mid-1980s. That attenuated rise partly reflects structural features cited earlier that have led to the closer integration of these two segments of the money markets. Part of the attenuated rise also could reflect the confluence of favorable cyclical circumstances--corporations and financial institutions had come a long way towards rebuilding their finances just before the Asian turmoil hit and governments of the United States, the United Kingdom, and Western Europe had worked hard to restore their finances as well. That meant that borrowers in commercial paper and London interbank markets warranted roughly similar credit-risk and liquidity premiums in the eyes of lenders. Historically though, industrial economies have not always faced similar credit-risk premiums and some allowance must be made for the possibility that cyclical circumstances--like those emerging during the Gulf War and recession period of 1990-91--might occur which would have uneven effects on commercial paper and London interbank markets and influence spreads.

#### A Model for Projecting Commercial Paper Rates and LIBOR

The structural approach taken here explains the decline in the spreads of commercial paper rates and LIBOR to TBill rates, and the reduced volatility of those spreads, by taking into account the fundamental factors affecting them. The approach works directly with the spreads, rather than the levels of rates, because CBO's outlook already includes projections for the interest rate on 3-month Tbills.

The most significant structural aspect affecting spreads favorably is the economy's overall improvement. Compared to the 1970s and 1980s, inflation has subsided, interest rates have declined, large federal deficits have lapsed, and monetary policy has been relatively stable. Those improvements are carried into the projections made by CBO--inflation and interest rates remain lower than in the past, the budget shows surpluses, and monetary policy continues to reflect this improved outlook. Incorporating this improved macroeconomic environment will lower projected spreads of both commercial paper rates and LIBOR relative to Treasury rates, and the spreads between commercial paper and LIBOR instruments as well, so long as the economy's overall improvement is expected to hold.

A second, related aspect of the economy's overall improvement--the decline in interest rate

volatility after the middle 1980s--affects the methodology of the approach. That decline remains even after taking into account the role played by the determinants of the spread. To economic statisticians, the observed change in volatility is referred to as "heteroskedasticity." Adjusting for its presence with specific procedures of analysis will enable the use of a sufficiently long historical sequence with which to detect quantitatively the role played by the determinants of the spread. In addition, and as will explained later on, taking into account the decline in volatility through such procedures will also improve estimates of the probability distribution of the range of variation in the spreads.

The balance of this section provides qualitative discussion and graphical results of the approach as applied to each spread, followed by a summary of results. The details of the statistical equations for each spread appear in the technical appendix.

#### One-month Commercial Paper-3-month Treasury Bill Spread

The first spread for which an outlook is prepared is that for the one-month commercial paper to three-month Treasury bill. An essential step in building a framework to project future values of the spread is to relate its historical behavior to the factors already described as most likely to influence it. One factor is the level of the TBill itself. Higher levels of the TBill rate would raise the spread, to the extent that the credit risk of commercial paper is proportional to the level of the rate on Tbills. Another factor is the stance of monetary policy which can be represented by the yield-curve spread between long-term and short-term Treasury rates. Typically, the wider the yield-curve spread the easier is monetary policy and the narrower is the spread between commercial paper and Tbill rates-possibly also because an easy monetary policy eases perceptions of risk. A third factor is the rate of inflation: the spread has tended to be high when inflation is high, probably because high rates of inflation have, in the past, been associated with high levels of volatility in markets and presumably heightened perceptions of credit risk. A fourth factor is volatility in the rate on federal funds as a proxy for uncertainty about monetary policy. Historically, it has had smaller effects on commercial paper rates than on London interbank dollar rates, probably because of the close connection between interbank dollar markets here and in London. Incorporating monetary-policy uncertainty here as well as in the LIBOR-Treasury bill rate spread is a way to take into account the possible effect of a more stable monetary policy on the narrowed gap between London interbank and commercial paper rates.

The projection relation between the spread and the determining factors just described draws on the historical data from 1971 to 1998. Data for that span are available for each of the four interest rates to be analyzed. The span also encompasses diverse regimes for interest rates, inflation, the stance and volatility of monetary policy, and the state of credit risk in banks and corporations who participate in commercial paper and interbank markets. The diversity provides a reasonable test of the usefulness of the framework for determining the spreads.

The projections also depend on projected values of the determining factors. Any departures of those factors in CBO's projections from their historical averages would then show up as a departure

of the spread from its historical average. For example, over the period from 1970 to 1998, inflation as measured by the consumer price index for all urban workers (CPIU), averaged about 5 percent. In CBO's January 1999 outlook, inflation over the next decade is projected to average just over 2.5 percent or about one-half the level of past decades. That can be expected to influence the projections of spreads to Treasury bill rates of rates on London interbank dollars and commercial paper compared to what those spreads have been in the past.

An illustration of the approach, using as the determining factors the level of the Tbill, the yieldcurve (as measured by the difference between rates on 10-year Treasury notes and 3-month Tbill), inflation, and monetary policy volatility (as defined in the annex of the Summary Table), is shown in the following figure (see Figure 10). It depicts the level of the spread between the 1-month commercial paper rate and the 3-month Treasury bill rate, the estimate of the level based on the determining factors over 1971 - 1998, and the projection for the years 1999 to 2009. In the exercise, the CBO's baseline of December 1998 is used for projections of the level of the Treasury bill rate, the yield curve, and CPIU inflation. For monetary-policy uncertainty, the average level of Fedfundsrate volatility in the 1990-1998 period is used. It is much lower than in the past and the assumption is that this relatively stable behavior of monetary policy will prevail.



Figure 10. Spread of 1-month Commercial Paper versus 3-month TBill

#### 3-month commercial paper-3-month Treasury bill spread

The outlook for the spread between rates on 3-month commercial paper and 3-month Treasury bills uses the same approach as before since both 1-month and 3-month commercial paper rates are influenced by approximately similar factors. The equation for this spread (3-month commercial paper - 3-month Treasury bill) uses the same variables as that for the previous spread (1-month commercial paper - 3-month Treasury bill). In contrast to the past, when this spread averaged smaller than the 1-month commercial paper, it predicts a fairly similar spread (see Figure 11). The main reason is the absence in the forecast period of shocks like those of the mid-1970s and early 1980s that drove the 1-month commercial paper rate to much higher levels than the rate on 3-month

commercial paper.



Figure 11. Spread of 3-month Commercial Paper versus 3-month Treasury Bill Rates

### One-month LIBOR - 3-month Treasury Bill Spread

The projection for the LIBOR-Treasury bill spread begins with the spread of the one-month LIBOR to the three-month Treasury bill rate. A successful procedure must be able to explain the historical behavior of the spread including the narrowing of the spread that was described earlier.

LIBOR-Tbill spreads should be influenced by the liquidity and credit-risk factors described earlier. As also described earlier, the likely determining factors are the level of the Treasury bill rate, the yield curve, inflation, and monetary-policy volatility. For example, fluctuations in the Tbill rate should have a more pronounced influence on the LIBOR-Tbill spread than on the commercial paper-Tbill spread to the extent interbank credit and liquidity risk are more influenced by the overall movement in interest rates. A steep yield curve also might affect the LIBOR-Tbill spread more to the extent easier monetary policy has stronger effects on the interbank market. High levels of inflation and higher monetary-policy volatility would also have stronger effects on credit-risk premiums in interbank markets for reasons given earlier. Application of these determining factors gives the following outlook for the LIBOR-Treasury bill rate spread (see Figure 12).



As can be seen above, the framework shows an ability to explain the LIBOR-Treasury bill spread over all three decades, 1970s, 1980s, and 1990s. As a result, the determining factors go a long way towards explaining why the LIBOR-commercial paper rate spread was wide before the 1990s, and why the spread has narrowed in this decade.

#### Three-month LIBOR -3-month Treasury Bill Rate Spread

The corresponding outlook for the spread between rates on 3-month LIBOR and 1-month LIBOR proceeds analogously to that of the 3-month and 1-month commercial paper spread and it is shown here (see Figure 13):



Figure 13. Spread of 3-month LIBOR versus 3-month Treasury Bill Rate

# Eurodollar Deposit Spreads versus 3-month Tbill Rates

Closely associated to LIBOR are Eurodollar deposits rates--the rates paid by banks in London and elsewhere other than in the United States to corporations and other investors outside the interbank community for deposits of dollar-denominated funds. Unlike LIBOR which is not available on a regular and frequent basis in any U.S. government publication, an estimate of Eurodollar deposit rates is made available, for reference purposes only, by the Federal Reserve on a daily basis in maturities of one, three, and six months. The estimates published by the Federal Reserve are bid rates for deposits quoted in London. Compared to LIBOR, rates on Eurodollar deposits have tended to be slightly lower (see Table 5).

Table 5. Average Spreads of LIBOR to Eurodollar Deposit Rates (in percentage points)						
LIBOR less Eurodollar:	1971-1998	1980-1998	1985-1998			
One-Month Rates	0.09	0.13	0.12			
Three-Month Rates	0.09	0.13	0.12			

Since there may be interest in using rates provided by the Federal Reserve, spread equations for one-month and three-month Eurodollar deposit rates to three-month Treasury bill rates have also been estimated. In both cases, the framework is the same as that used for the LIBOR-Treasury bill spreads. The results are shown in Figures 14 and 15 and included in the Summary table to follow.

Figure 14. One Month Eurodollar - T-Bill Spread



Figure 15. Three Month Eurodollar - T-Bill Spread



TABLE 6.Illustrative Baseline for Commercial Paper Rate, LIBOR, and<br/>Eurodollar Rates using CBO Outlook of January 1999.

	3-month Treasury Bill	1-month Commercial Paper Spread	3-month Commercial Paper Spread	1-month LIBOR Spread	3-month LIBOR Spread	1-month Eurodollar Spread	3-month Eurodollar Spread
1971-98 average	6.73	0.53	0.39	1.13	1.31	1.04	1.22
1998(actual)	4.79	0.63	0.58	0.78	0.77	0.66	0.66
1999	4.45	0.46	0.48	0.73	0.60	0.53	0.55
2000	4.50	0.44	0.45	0.74	0.65	0.56	0.59
2001	4.50	0.42	0.42	0.74	0.68	0.56	0.62
2002	4.50	0.42	0.42	0.74	0.68	0.56	0.62
2003	4.50	0.42	0.42	0.74	0.68	0.56	0.62
2004	4.50	0.42	0.42	0.74	0.68	0.56	0.62
2005	4.50	0.42	0.42	0.74	0.68	0.56	0.62
2009	4.50	0.42	0.42	0.74	0.68	0.56	0.62

Spreads to 3-month Tbill of 1- and 3-month Rates for Commercial Paper, LIBOR, and Eurodollars

Levels: 3-month Tbill, 1- and 3-month Rates for Commercial Paper, LIBOR, and Eurodollars

	3-month Treasury Bill	1-month Commercial Paper	3-month Commercial Paper	1-month LIBOR	3-month LIBOR	1-month Eurodollar	3-month Eurodollar
1998(actual)	4.79	5.42	5.37	5.57	5.56	5.45	5.45
1999	4.45	4.91	4.91	5.18	5.05	4.98	5.00
2000	4.50	4.95	4.94	5.24	5.15	5.06	5.09
2001	4.50	4.92	4.93	5.24	5.18	5.06	5.12
2002	4.50	4.92	4.93	5.24	5.18	5.06	5.12
2003	4.50	4.92	4.93	5.24	5.18	5.06	5.12
2004	4.50	4.92	4.93	5.24	5.18	5.06	5.12
2005	4.50	4.92	4.93	5.24	5.18	5.06	5.12
2009	4.50	4.92	4.93	5.24	5.18	5.06	5.12

SOURCE:

Why do the long-run values in all cases fall below the historical averages? The main reason stems from CBO's outlook. Compared to history, the Treasury bill rate is lower, the yield curve is flatter, inflation is lower, and the volatility of the rate on Fedfunds is assumed to be lower (see Table 7).

Table 7. Average Levels of Determining Factors: 1971-1998 versus 1999-2009							
	3-month Tbill	Treasury yield curve	Inflation	Fedfunds Volatility			
1971-1998:	6.73	1.64	5.03	1.14			
1999-2009:	4.50	0.87	2.61	0.72			

### **Forecast of Volatility of Alternate Instruments**

In order to estimate the cost associated with the federal student loan programs, CBO analysts require knowledge of more than just the baseline path of interest rates. Since special allowance payments to lenders are triggered if interest rates exceed certain predetermined thresholds during the projection period, the cost of the program depends on both the baseline path of a particular interest rate and on the volatility associated with that path. Therefore, any cost estimate for the student loan program requires an estimate of both a mean and a variance for each interest rate.

CBO used Monte Carlo simulations to estimate the uncertainty surrounding the baseline forecasts of the alternate interest rates. Monte Carlo simulations are a technique of statistical inference used to assess the uncertainty in estimates and projections of economic variables. A common application would be to use this technique to approximate the sampling distribution of a test statistic, for example, a parameter in a regression equation. In the current analysis, the method was used to estimate the probability distribution associated with the baseline forecasts of LIBOR and commercial paper rates.

The basic concept underlying the Monte Carlo simulations is relatively simple. It involves constructing a large number of simulated (or hypothetical) projections of an economic variable, such as an interest rate, and computing the distribution of the resulting projections. The baseline forecasting equations--which determine each spread as a function of the 91-day Treasury bill rate, the yield curve, CPI inflation, and a measure of interest rate volatility-are used to compute the simulated forecasts. To model the uncertainty inherent in the future evolution of the alternate rates, random variation is added to each equation via two channels.

First, rather than being held to baseline levels, the explanatory variables in each equation were simulated randomly. Doing so allows uncertainty about the future vagaries of the overall economy to affect the spreads. Second, for each period of the simulation, each of the spread equations was shocked using a random variable that is based on the historical properties of the residuals from that equation. Each of the simulated forecasts starts at the same level and evolves according to the baseline forecasting equation, but each incorporates a different path for the explanatory variables and a different set of random shocks.

#### Uncertainty Associated With Explanatory Variables

CBO's baseline projection for each alternate interest rate is determined by the baseline projection wfor each of the explanatory variables in the equation. However, the future behavior of those variables is not known with complete certainty. Indeed, the baseline projection is only one of an infinite number of paths that the explanatory variables could follow in the coming years. To model the uncertainty that stems from the explanatory variables, CBO calculated simulated paths for the explanatory variables and then used those paths to calculate the simulated forecasts for the alternate instruments.

When constructing a set of simulated projections, it is important that the projection for each variable is consistent with the historical behavior of that variable and with the projections for all of the other explanatory variables. To ensure both types of consistency, one must use a model, or system of interrelated equations, to compute the hypothetical projections of the explanatory variables.

CBO uses an econometric model to compute its baseline set of economic assumptions. However, that model is too large to use for stochastic simulations, so CBO adopted a simpler approach used by time-series analysts, that of Vector Autoregression, or VAR. Vector Autoregression is a method by which the statistical relationships among a set of economic variables can be estimated without placing many *a priori* restrictions on those relationships. In effect, it allows the data to determine which links among the variables are strong and which are weak. In contrast, traditional methods use economic theory to place as many restrictions as possible on the structure of statistical models to make estimation easier. Advocates of VARs contend that such restrictions are inappropriate because, in a complex economy, most variables in macroeconomic models are endogenous (that is, they are affected by the other variables in the system).

Under the VAR approach, a system in which all of the variables are endogenous can be expressed as a series of equations, in which each variable is expressed as a function of its own lagged values and the lagged values of all of the other variables of the system. Each equation in the system can be estimated using Ordinary Least Squares (OLS) because the right-hand side of each equation contains only predetermined variables. Estimating a VAR involves little more than determining the variables to be included in the system and how long the lags should be.

CBO's VAR includes the following variables: the 10-year Treasury note rate, the spread between the 10-year note rate and the three-month Treasury bill rate, the rate of CPI inflation, the rate of unemployment, a measure of volatility, and the spread between the 10-year note rate and the 30- year Treasury bond rate. Each equation includes three lags of each variable in the model and is estimated using quarterly data from 1961 through the third quarter of 1998. The results are not sensitive to the length of the lag used.

#### Uncertainty Associated with Alternate Rates

The second source of random variation in the simulations for the alternate rates stems from the residuals of the baseline forecasting equations. When estimated over history, regression equations do not explain all of the variation in the dependent variable. The errors in regression equations are known as the residuals and are assumed to result from completely random shocks to the dependent variable. To capture the uncertainty imparted by these random shocks in the simulations, a shock term is added to the value of the spread that is predicted by the baseline forecasting equation. These shocks, however, are not random draws from a statistical distribution.

Statistical tests indicated that the residuals of the spread equations were heteroskedastic, which means that they did not have constant variance throughout the sample. CBO's estimation corrected for heteroskedasticity by exploiting the fact that the variance of the residuals was positively correlated with the rate of inflation.<sup>3</sup> The method used to correct for heteroskedasticity, which improved the statistical efficiency of the baseline spread equations, also supplied the shocks that were applied to the baseline equations. The practical impact of the correction was to reduce the estimated volatility of the interest rates during the projection period because the variance of the residuals of the interest rates is positively related to the rate of inflation. Since CBO's projection for inflation is lower than the historical average, the variance imposed in the simulated projections is lower than that observed during the historical sample.

### Probabilities Associated With Alternate Rates

A set of illustrative probabilities associated with each of the alternate rates is presented in Table 8, below, along with probabilities for the 91-day Treasury bill rate. The probabilities are computed from a series of 1,000 simulations of the model, where each simulation is a forecast from the model that includes the two sources of random variation described above. Once the simulated forecasts have been computed, it is straightforward to count the number of occurrences (out of 1,000) in which the interest rate exceeded a specific threshold and approximate the distribution of forecasts.

Each of the alternate rates is highly correlated with the three-month Treasury bill rate, so it is not surprising that the probabilities associated with the alternate rates are broadly similar to that of the bill rate. For the 91-day CP rate, in particular, the distribution of estimated probabilities is almost indistinguishable from that of the bill rate. Probabilities for the one-month CP rate are only slightly higher. LIBOR rates appear to be more volatile, with estimated probabilities exceeding those of the bill rate by slightly larger amounts.

<sup>3.</sup> CBO used an estimation technique known as generalized autoregressive conditional heteroskedasticity (GARCH) to correct for the heteroskedasticity displayed by the residuals. The technique adds a regression equation which explains the variance of the residuals (see technical appendix).

	Probability That Interest Rate Will Exceed Baseline Rate						
	By At Least Percentage Points During Forecast Period						
	0 pp	1 рр	2 pp	3 рр	4 pp		
3-Month Treas. Bill	49	33	20	10	5		
1-Month C. P.	49	34	22	12	6		
3-Month C.P.	49	34	20	11	5		
1-Month LIBOR	49	36	24	14	8		
3-Month LIBOR	49	36	24	15	9		

Notes: CBO's model calculates the probability that an interest rate will exceed its baseline level (by 0 percentage points, 1 percentage point, and so forth) for each year from 1999 through 2030. Entries in the table are averages of those probabilities for the period 1999 - 2030.

pp = percentage points C.P. = commercial paper LIBOR = London Interbank Offered Rate

# TECHNICAL APPENDIX: ESTIMATION METHODOLOGY AND ECONOMETRIC DETAIL

TABLE 8: Illustrative Probabilities for Short-Term Interest Rates

The projections have been prepared using a statistical model whose determining factors were discussed in the text. To recapitulate, a model for the behavior of each spread is approximated as a function of: the level of the 3-month Tbill rate to capture covariations between credit-risk and the overall level of interest rates; the spread between a long-term and short-term interest rate to capture the influence of the stance of monetary policy on liquidity and credit risk; the level of inflation to capture the effect of overall market uncertainties affecting credit risk; and the volatility of the interest rates such as commercial paper and London dollar rates. The models differ among the spreads according to the different size of the impact of the determining factors on each spread--that is, each equation has the same set of explanatory variables, but a different set of coefficients.

The methodology for estimating the model draws from standard econometric theory in selecting the appropriate form of the spread and the techniques to be applied. A summary of the methodology is incorporated in the following set of equations, and the discussion which follows.

### **Equation 1. Spread over Tbill**:

$$\ln\{\frac{(1+R_{j,t})}{(1+R_{Tbill,t})}\} = a_{j,0} + a_{j,1} \ln\{1+R_{Tbill,t-1}\} + a_{j,2} \ln\{\frac{(1+R_{Tnote,t-1})}{(1+R_{Tbill,t-1})}\} + a_{j,3} \ln\{1+Inflation_{t-1}\} + a_{j,4} \ln\{1+\sigma_{Fedfunds,t-1}\} + a_{j,5}D74Q3 + a_{j,6}D80q4 + u_{j,t}$$

where, for  $R_{j,t}$ , the upper case, R, signifies an interest rate and the subscript j stands respectively for 1-month commercial paper, 3-month commercial paper, 1-month LIBOR, 3-month LIBOR, 1-month Eurodollar, and 3-month Eurodollar; "In" signifies the natural logarithm of the expression within braces; the two variables preceded with an upper case D signify ( for reasons described later) that the variable takes on the value one in the year and quarter (1974Q3, and 1980Q4) and zero otherwise; and the variable  $u_{i,t}$  represents unobservable random factors.

In equation 1, the spread appears in ratio form as shown to the left of the equality sign. It is expressed as the logarithm of ratio of one plus the interest rate under examination to one plus the rate on 3-month Treasury bills. This form of the spread is approximately equal to the numerical difference between interest rates when the level of rates is small. It was chosen to help reduce the effect of extreme values of the spread on the statistical estimates of parameters  $(a_0, ...., a_6)$ .<sup>4</sup> Even so, two extreme values of the spread occurred in the third quarter of 1974 and the fourth quarter of 1980 that were still sufficiently large and unaccounted for by the determining factors despite the logarithmic transformation. As a result, the two variables, D74Q3 and D80Q4, were introduced to help remove the effects of those two extreme values on the parameter estimates.

<sup>4.</sup> For example, it reduces peak values of the spread between 1-month LIBOR and 3-month Tbills by about 40 to 50 basis points compared to that constructed as the simple difference between the two rates.

#### **Equation 2. Residual Volatility (ARCH Model):**

 $\ln \{u_{j,t}^{2}\} = b_{j,0} + b_{j,1} \ln \{u_{j,t-1}^{2}\} + b_{j,2} \ln \{1 + Inflation_{t}\}$ 

Equation 2 is that part of the structural model which helps to account for nonuniform variations in the volatility of the spread such as that in the period before the middle 1980s when inflation was climbing and high versus that in the period since then when inflation has declined and become low. Nonuniform volatility introduces heteroskedasticity. Its systematic variation, characterized in part by a clustering of large values followed by a period of relative calm, has given rise to the term "autoregressive-conditional-heteroskedasticity," or ARCH, to signify this type of time variation.

Accounting for ARCH as in equation 2 improves the empirical estimates of the parameters of equation 1 over longer data intervals such as the nearly 30 year period encompassing the 1970s through 1990s. Otherwise, the potential range of variation around the estimated values of the parameters in equation 1 might be too large to yield much confidence in the estimates themselves. An unattractive alternative would be to shorten the period of analysis--unattractive because using a shorter the period, such as the 1990s alone or the late 1980s to late 1990s for example, limits the ability to gauge the role played by the determining factors in the behavior of the spread.

But the inclusion of ARCH also helps importantly in developing sensible probability ranges in the projection span. In particular, as specified in equation 2, the low inflation of the 1990s turns out to have played an important role in reducing volatility. As such, a baseline projection of low inflation in the years ahead contributes to projections with a lower volatility of the spread than otherwise. That, in turn, produces probability ranges that are lower than otherwise.

The estimation of equations 1 and 2 involves a sequence of three steps that comprise the method of generalized least squares. In the first step, equation 1 is estimated by ordinary least squares to derive an estimate of the unobservable series of residuals,  $u_{j,t}$ . Appendix Table 1 shows the estimates of equation 1 for each of six spreads. The difference between the actual value of the spread and the value predicted by the equation yields the residuals used in the second step.

In the second step, the residuals obtained from the first step are squared to obtain the volatility of the spread. This measure of volatility is used along with the inflation rate to estimate equation 2 for each of the six spreads. Appendix Table 2 shows the estimates for equation 2. From this equation, the predicted values of volatility are retrieved for the final step of generalized least squares.

In the third and final step of generalized least squares the square root of the predicted values of volatility are divided into all the observable variables of equation 1 and the resulting equation is estimated by ordinary least squares. Appendix Table 3 shows the generalized least squares estimates of equation 1 for each of the six spreads.

# APPENDIX TABLE 1: ORDINARY LEAST SQUARES ESTIMATES OF INTEREST-RATE SPREADS Dependant Variable: ln{(1+Rate)/(1+Tbill)}, where Rate = {Commercial Paper, LIBOR, Eurodollar}.

Estimation interval: 1971Q2 - 1998Q3

	Commercial Paper		<u>LIBOR</u>		<u>Eurodollar</u>	
Determinants	1-month	3-month	1-month	3-month	1-month	3-month
constant	.0028	.0048	.0014	0001	.0009	0008
(t-Stat)	(2.325)	(4.174)	(0.671)	(-0.049)	(0.406)	(-0.319)
ln(1+Tbill <sub>-1</sub> )	.0628	0093	.0986	.0939	.0794	.0763
(t-Stat)	(4.613)	(-0.721)	(4.126)	(3.830)	(3.225)	(3.143)
ln(1+Tnote <sub>-1</sub> )/(1+Tbill <sub>-1</sub> )	1017	0132	1821	1221	2003	1380
(t-Stat)	(-3.571)	(-0.489)	(-3.642)	(-2.379)	(-3.887)	(-2.717)
ln(1+inflation <sub>-1</sub> )	.0147	.0115	.0464	.0837	.0598	.0909
(t-Stat)	(1.179)	(0.973)	(2.115)	(3.716)	(2.646)	(4.077)
ln(1+Fedfunds Volatility <sub>-1</sub> )	0126	0093	.0251	.0326	.0302	.0397
(t-Stat)	(-2.397)	(-1.861)	(2.715)	(3.435)	(3.166)	(4.224)
D1974Q3	.0123	.0063	.0208	.0228	.0204	.0236
(t-Stat)	(4.503)	(2.423)	(4.325)	(4.614	(4.108)	(4.823)
D1980Q4	.0060	0079	.0141	.0070	.0137	.0077
(t-Stat)	(2.208)	(-3.073)	(2.929)	(1.434)	(2.801)	(1.600)
Measures of Fit: R-bar Squared	.574	.130	.640	.652	.669	.670
Standard Error, basis points	26	27	47	48	48	47
F(6,103)	25.46	3.72	33.33	35.02	33.16	37.91
Measures of Residual Randomness: D.W.	1.11	1.13	0.77	0.83	0.64	0.79
Q(4)	48.4	19.0	62.9	26.5	52.8	35.6
first order autocorrelation coefficient:	.442	.432	.569	.541	.568	.561

# APPENDIX TABLE 2: AUTOREGRESSIVE-CONDITIONAL HETEROSKEDASTIC (ARCH) MODEL OF SQUARED RESIDUALS

 $\ln u_t^2 = \text{constant} + \alpha \ln u_{t-1}^2 + \beta \ln(1 + Inflation_t)$ 

# Estimation Interval: 1971Q3 - 1998Q3

	<u>Commercial Paper</u>		<u>LIBOR</u>		<u>Eurodollar</u>	
Determinants	1-month	3-month	1-month	3-month	1-month	3-month
constant	-12.722	-11.964	-8.013	-11.259	-8.627	-8.645
(t-Stat)	(-8.665)	(-8.964)	(-6.387)	(-8.013)	(-6.782)	(-7.718)
$\frac{\ln(\sigma^2_{-1})}{(t-Stat)}$	.133	.181	.400	.191	.367	.370
	(1.386)	(1.974)	(4.498)	(2.020)	(4.123)	(4.285)
ln(1+Inflation)	24.451	20.545	13.891	26.920	16.990	20.526
(t-Stat)	(2.872)	(3.009)	(1.944)	(2.745)	(2.112)	(3.061)
Measures of Fit:						
R-bar Squared	.098	.107	.226	.120	.196	.264
Standard Error	2.38	1.98	1.974	2.73	2.269	1.855
F(2,106)	6.87	7.49	16.78	8.35	14.14	20.42

# APPENDIX TABLE 3:

# GENERALIZED LEAST SQUARES ESTIMATES OF INTEREST-RATE SPREADS

 $Dependant \ Variable: \ [ln{(1+Rate)/(1+Tbill)}]/\sigma, where \ \sigma \ is the square root of the fitted values from the ARCH model.$ 

### Estimation Interval: 1971Q3 - 1998Q3.

	<u>Commercial Paper</u>		<u>LIBOR</u>		<u>Eurodollar</u>	
Determinants:#	1-month	3-month	1-month	3-month	1-month	3-month
constant	.0022	.0049	.0007	0020	0010	0020
(t-Stat)	(2.581)	(6.021)	(0.596)	(-1.453)	(-1.009)	(-1.630)
ln(1+Tbill <sub>-1</sub> )	.0776	0005	.1041	.1125	.1167	.0921
(t-Stat)	(6.556)	(-0.053)	(5.401)	(6.416)	(6.761)	(4.926)
$\frac{\ln(1+\text{Tnote}_{-1})}{(1+\text{Tbill}_{-1})}$ (t-Stat)	0854	0450	1727	1046	1617	1229
	(-3.890)	(-2.214)	(-5.082)	(-2.626)	(-5.647)	(-3.525)
ln(1+inflation <sub>-1</sub> )	.0079	.0038	.0657	.0607	.0329	.0744
(t-Stat)	(0.689)	(0.384)	(4.297)	(3.214)	(2.651)	(4.470)
ln(1+Fedfunds Volatility.1)	0153	0067	.0224	.0407	.0261	.0440
(t-Stat)	(-3.285)	(-1.640)	(2.694)	(4.745)	(3.402)	(5.433)
D1974Q3	.0130	.0059	.0195	.0246	.0230	.0249
(t-Stat)	(2.182)	(1.319)	(1.847)	(2.160)	(2.208)	(2.187)
D1980Q4	.0061	0078	.0127	.0080	.0148	.0083
(t-Stat)	(1.316)	(-1.943)	(1.591)	(0.981)	(1.903)	(1.073)
Measures of Fit: R-bar Squared	.485	.276	.782	.515	.793	.650
Standard Error, basis points	26	25	43	45	45	44
Measures of Residual Randomness: D.W.	1.05	1.03	1.22	0.85	0.98	1.05
Q(4)	49.0	23.6	35.6	44.3	32.7	32.9
first order autocorrelation coefficient:	.464	.480	.358	.521	.463	.450

# Determinants all divided by,  $\sigma_i$ , the square root of the fitted values from the ARCH model.

Notes to Models: Variables:

**Commercial Paper Rates:** 

Quarterly average of daily data published in Federal Reserve release H.15. Data before 1997 fourth quarter based on historical statistics gathered by Federal Reserve Bank of New York. Data for 1997 fourth quarter and later gathered by Depository Trust Company and reported to Federal Reserve Bank of New York.

London Interbank Offer Rates:

Quarterly average of daily data published by the British Bankers' Association.

Eurodollar Deposit Rates:

Quarterly average of daily data published in Federal Reserve release H.15.

Tbill Rate:

Quarterly average of daily data on 3-month Treasury Bill Rate, secondary market, discount basis.

10-Year Tnote Rate:

Quarterly average of daily data on 10-year Treasury note, constant maturity.

Inflation:

Annualized quarterly percentage change of consumer price index (all urban), where price index is quarterly average of monthly levels.

#### Fedfunds Volatility:

Square root of 8-quarter moving average squared deviation of Fedfunds rate. Deviation is measured as difference between log first difference-change of Fedfunds rate and trend of log first-difference change in Fedfunds rate. Trend is measured as 8 quarter moving average. Quarterly data based on average of daily data as published in Federal Reserve release H.15.

# Statistics:

*t-statistic* --tests the significance of individual parameter estimates;

*F-statistic* --tests the significance of the combined set of parameter estimates;

Standard error of estimate--measures the range of variation around the model's projection.

Measure of fit-- the proportion of total variation explained by model;

*Measure of residual randomness*-- D.W. reveals whether omitted factors are correlated from quarter-to-quarter (the nearer a value is to 2, the more it suggests the absence of such correlation; Q = Box-Pierce Q-statistic is a general test of randomness [G.E.P. Box and D.A. Pierce, "Distribution of residual autocorrelations in autoregressive-integrated moving average time series models," *Journal of American Statistical Association*, vol. 65, 1970, pp.355-365.]